REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
11 November 2004	Technical Report	Oct 2001-Sep 2004

4. TITLE AND SUBTITLE

Midway revisited: Detecting Deception by Analysis of Competing Hypothesis

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Frank J. Stech and Christopher Elsaesser

5d. PROJECT NUMBER
51MSR111

5e. TASK NUMBER
A4

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

The MITRE Corporation
7515 Colshire Drive
McLean, Virginia 22102-7508

8. PERFORMING ORGANIZATION REPORT NUMBER
Case Number 04-0813

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for Public Releases; Distribution Unlimited

20041213 319

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Historical accounts of military deception abound, but there are few historical accounts of counter-deception, and fewer operational theories. This paper describes a business process and semi-automated tools for detecting deception. The counter-deception business process begins with hypothesis generation. This consists of automated course of action generation in tactical situations; strategic situations require hypothesis elicitation from analysts. Next, hypotheses and related potential evidence are represented by a Bayesian belief network. This network is the basis of a diagnostic analysis derived from classification theory. The result is a weighted list of possible observations that: (1) identify distinguishing evidence that a deceiver must hide and a counter-deceiver must uncover, (2) isolate local deception in intelligence reporting and sensing from global deception, and (3) identify circumstances when it might be fruitful to entertain additional hypotheses. We illustrate this process by describing how it could have been used by the Japanese Navy before the Battle of Midway to detect the American denial and deception tactics.

15. SUBJECT TERMS

Counter-deception; deception detection; military deception; intelligence analysis; Battle of Midway; World War Two; Analysis of Competing Hypotheses; U.S. Navy; Japanese Imperial Navy; Bayesian belief network

16. SECURITY CLASSIFICATION OF: UNCLASSIFIED

a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	NONE		Frank J. Stech

19b. TELEPHONE NUMBER *(include area code)*
703-883-5957

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Midway Revisited: Detecting Deception by Analysis of Competing Hypothesis

Frank J. Stech and Christopher Elsaesser
The MITRE Corporation
7515 Colshire Drive
McLean, Virginia 22102-7508
Phone Numbers: 703-883-5920, 703-883-6563
Fax: 208-979-3654
E-mail Addresses: stech@mitre.org & chris@mitre.org

72nd MORS Symposium
Working Group 8
22-24 June 2004 (dated prepared 11 November 2004)

ABSTRACT

Historical accounts of military deception abound, but there are few historical accounts of counter-deception, and fewer operational theories. This paper describes a business process and semi-automated tools for detecting deception. The counter-deception business process begins with hypothesis generation. This consists of automated course of action generation in tactical situations; strategic situations require hypothesis elicitation from analysts. Next, hypotheses and related potential evidence are represented by a Bayesian belief network. This network is the basis of a diagnostic analysis derived from classification theory. The result is a weighted list of possible observations that: (1) identify distinguishing evidence that a deceiver must hide and a counter-deceiver must uncover, (2) isolate local deception in intelligence reporting and sensing from global deception, and (3) identify circumstances when it might be fruitful to entertain additional hypotheses. We illustrate this process by describing how it could have been used by the Japanese Navy before the Battle of Midway to detect the American denial and deception tactics.

INTRODUCTION

This paper considers counter-deception from a psychological, rather than cultural perspective. First, we summarize the cognitive aspects of counter-deception. Next, we describe a process developed in the intelligence community called the Analysis of Competing Hypotheses (ACH). We describe how we correct ACH to account for cognitive factors that make people poor at detecting deception. We call this modified process ACH-CD. Then we describe semi-automated tools that demonstrate that ACH-CD is sufficient for counter-deception. Finally, we demonstrate how the modified process provides a basis for military counter-deception with a demonstration and descriptive application to the battle of Midway, from Japan's perspective.

Why is Counter-deception hard?

In this paper, the term *counter-deception* means detecting or recognizing a deception. Note that successful counter-deception does not necessarily imply that one knows the adversary's true course of action. We use the term *deception* to include denial, or hiding, which we consider a component of deception behavior, and deceptive misleading or dissimulation.

Put simply, people are deceived because they do not systematically consider alternative explanations for the evidence they observe (Johnson, et al 2001, Heuer 1981, Heuer 1999, Whaley and Busby 2002) and incorrectly weigh the evidence they do have (Dawes 2001). These behaviors occur because of memory limitations and related reasoning heuristics that evolved to deal with a high base rate world (Gilovich et al. 2002). The result is that people often dismiss important evidence, prematurely prune alternative hypotheses, and jump to conclusions. These make people and organizations easy to deceive.

Johnson and his associates (2001) note that human evidential reasoning is mainly adequate for frequently experienced events. Reasoning heuristics that evolved to be cognitively efficient and effective in our high-base rate world often result in biased reasoning – grossly over or under estimating probabilities – when one is faced with low-base rate events such as deception (Gigerenzer et al 1999). Since deception is relatively rare, it is not surprising that people are poor at counter-deception. Heuristics can result in the following analytic errors that hinder effective counter-deception:

- *Poor anomaly detection:* Analysts miss environmental cues of anomalies, or prematurely dismiss anomalies as irrelevant or inconsistent with other intelligence. (We do not intend to imply that counter-deception is mainly a process of anomaly detection, in the statistical sense. We use the term *anomaly* to denote evidence that is not consistent with the analyst's current beliefs or expectations about the state of the world or the predicted actions of an adversary);
- *Misattribution:* inconsistent or anomalous events are often attributed to collection gaps or processing errors, rather than to deception tactics;
- *Failure to link denial and deception tactics to deception hypotheses:* When they do notice anomalies, analysts often fail to recognize anomalous evidence as indicators of denial and deception tactics, possibly suggesting strategic deception objectives;
- *Inadequate support for deception hypotheses:* Analysts fail to link their assessment of an adversary's deception tactics to the adversary's strategic goals; i.e., analysts fail to test denial or deception courses of action (COAs) against all the available evidence.

Counter-Deception Business Process Model

Johnson et al (2001) conducted a cognitive task analysis of forensic accountants performing counter-deception auditing analysis with varying degrees of success. Johnson et al developed a four-part analysis business process to describe and address the four problematic heuristics summarized above. In this paper we describe how we adapted and augmented the "Analysis of Competing Hypotheses" technique for deception detection to address one key part of this business process. We are also identifying and adapting useful theories or algorithms for the other components of the Johnson et al counter-deception business process model.

The other counter-deception theories we applied to the Johnson et al counter-deception business process model are:

- Whaley & Busby's (2002) "Congruity Theory & Ombudsman Method" explicitly address the problem of *Poor anomaly detection* by identifying data collection techniques likely to surface anomalies related to denial or deception tactics.

- R. V. Jones's (1978, 1989, 1993) "Theory of Spoof Unmasking" can be adapted to address the problem of *Misattribution*, i.e., to avoid attributing inconsistent or anomalous events to collection gaps or processing errors rather than to denial or deception tactics. Jones advocates analysis of anomalies through the use of multiple channels of intelligence (e.g., signal intelligence--SIGINT, imagery intelligence--IMINT, open source intelligence—OSINT) applied to anomalies, examined at various resolutions (both higher and lower). We would add tat analysts should compare not only the expected means of these observations to base-rate data, but also the anomalous data's variance and skewedness, since anomalies whose averages seem normal may be revealed as deceptive because the data do not vary, or vary in the normal directions, as do base-rate data. Finally, Jones advises "natural" or planned operational "experiments" that force the enemy to provide additional intelligence that will highlight possible denial or deception tactics. At the Battle of Midway, the Americans used an operational experiment to confirm that the main Japanese target was Midway Island and not one of the several Japanese diversionary targets. Midway defenders signaled Hawaii in the clear that the island's water purification system was off-line. Japanese SIGINT picked up the bait and alerted Tokyo that "AF," codename of the main target of the Japanese operation, was short of water, thus linking the Midway bait to the Japanese plans that American SIGINT analysts had already intercepted and reconstructed.

- We adapted Heuer's "Analysis of Competing Hypotheses" (ACH, Heuer 1999) technique for counter-deception analysis to address the *Failure to link denial and deception tactics to deception hypotheses.* This adaptation assesses the likelihood of indicator events and evidence across probable COAs, including denial and deception and separately assesses anomalies due to sensors, collection, or processing errors and anomalies due to denial or deception, i.e., the issue of "local versus global deception."

- Finally, Johnson et al's (2001) "Cognitive Model of Fraud and Deception Detection" organizes these four parts into a counter-deception business process (Figure 1) that specifically addresses the problem of *Inadequate support for deception hypotheses.* Johnson et al appreciate the need to address the sensitivities of hypotheses (or COAs) to the indicators of denial and deception tactics (anomalous evidence) in order to effectively focus intelligence collections and operational intelligence experiments, to confirm suspicions of deception, and to reduce the uncertainties of deception estimates. They also note the importance of the intelligence analyst making an adequate case for deception detection. Often deceptions are constructed on a foundation of the preconceptions of the analyst's customers, who will be reluctant to forsake these preconceptions without a strong case being made by the analyst for the deception hypotheses.

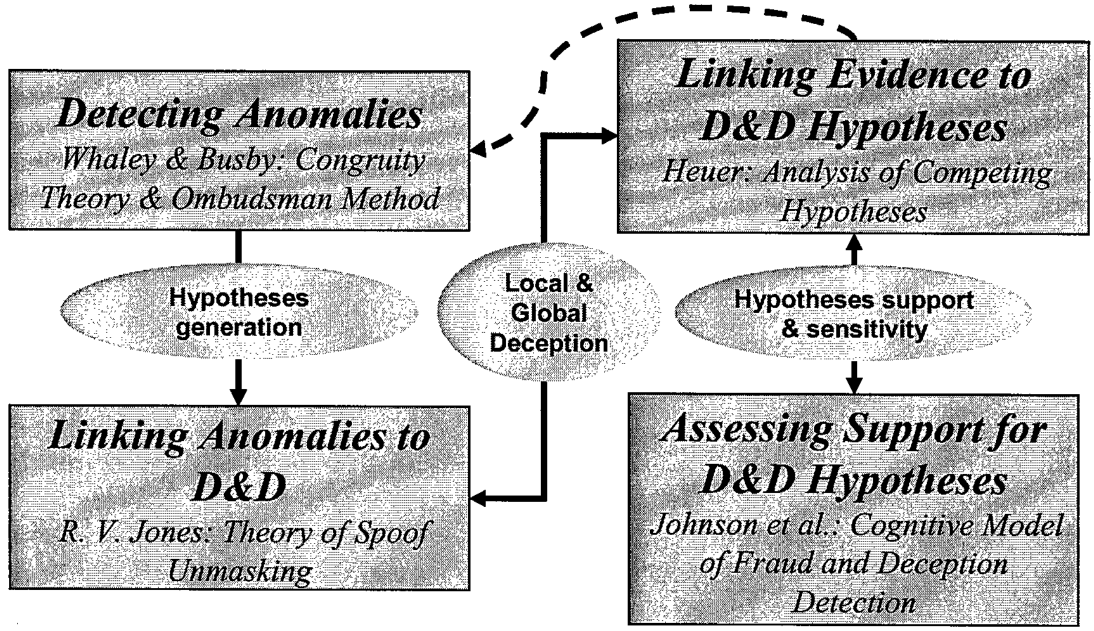

Figure 1: Counter-deception business process

What is an analyst to do?

Anyone who reads the newspapers knows that deception plagues the intelligence community. Heuer (1999) developed a protocol called Analysis of Competing Hypotheses (ACH) in part to address analysts' susceptibility to deception. ACH consists of the following steps (simplified and slightly reordered; see Heuer 1999 for the original eight-step formulation):

1. Prepare a matrix listing hypotheses vs. evidence.
    a. Identify the possible hypotheses to be considered.
    b. List significant observed evidence and assumptions for and against each hypothesis.
2. Draw tentative conclusions about the relative likelihood of each hypothesis, based on the evidence, focusing on evidence which is inconsistent with hypotheses.
3. Analyze sensitivity of the conclusion to a few critical items of evidence.
4. Report conclusions.
5. Identify future observation that may indicate events are taking a different course than expected.

ACH helps analysts to compare evidence, arguments, and assumptions (e.g., intelligence) to possible hypotheses (estimates of the situation or courses of actions). ACH ensures alternative hypotheses are considered equally and fully and that the information value of the evidence and assumptions is applied to the hypotheses. Structuring helps analysts probe and challenge evidence and assumptions and test the support for the hypotheses. Heuer wrote:

"Simultaneous evaluation of multiple, competing hypotheses ... takes far greater mental agility than listing evidence supporting a single hypothesis that was pre-judged as the most likely answer. It can be accomplished, though, with the help of the simple procedures....The ACH procedure has the...advantage of focusing attention on the few items of critical evidence that cause the uncertainty or which, if they were available, would alleviate it. This can guide future collection, research, and analysis to resolve the uncertainty and produce a more accurate judgment."

Lately, several U.S. intelligence agencies have advocated using ACH to enhance intelligence analysis and estimation. For example, the Central Intelligence Agency offers its analysts workshops on "Alternative Analysis" methods (Directorate of Intelligence 2002). The CIA re-published Heuer's *The Psychology of Intelligence Analysis* in 1999 and posted Heuer's book on the CIA's website. Morgan Jones, who learned ACH as a CIA analyst, featured the technique prominently in his book, *The Thinker's Toolkit: Fourteen powerful techniques for problem solving* (Jones 1998), which is also cited widely in U.S. intelligence agency analyst training.

Adapting ACH for Counter-Deception

Our concern is that ACH could lead analysts to be *more susceptible to deception.* In particular, step 2 suggests weighing hypotheses in light of evidence ($p(\text{Hi}|\text{E})$, an heuristic Dawes (2001) notes as responsible for many of the reasoning errors he dubs "everyday irrationality." The problem with step 2 is that $p(\text{Hi}|\text{E})$ neglects the base rates of the evidence, $p(\text{E})$, and the hypothesis, $p(\text{Hi})$. The prior probability of H, being mainly subjective, can be a source of bias.

Neglect of base rates features prominently in many writings on evidential reasoning errors (e.g., Burns 2004a, b, c), for example, foster the confirmation bias if analysts observe evidence that is consistent with H, even when the evidence might be consistent with alternate hypotheses. The confirmation bias results in $p(\text{H}|\text{E})$ being greater than $p(\text{H})$, which may already reflect bias. But more important for counter-deception reasoning, assessing ($p(\text{Hi}|\text{E})$ fails to direct the analyst's attention to the false positive rate of the evidence, $p(\text{E}|\text{ not Hi})$.

People are much more susceptible to deception if they do not normatively account for both $p(\text{E}|\text{ Hi})$ and $p(\text{E}|\text{ not Hi})$. They allow a deceiver to simulate evidence that is often associated with, but not necessary for a particular course of action (hypothesis). They also are prone to the confirmation bias if they observe things that are consistent with more than one hypothesis.

To illustrate, consider a hypothetical strategic deception. Say intelligence collection detects Krypton gas in some Middle Eastern country. This suggests the conclusion that the target country may have an active nuclear weapons program, since Krypton gas is a by-product of uranium enrichment. The argument might be summarized this way:

Detect Krypton

p(enrichment | Krypton) = high → p(enrichment program) = high

Leading to:

p(nuclear program) = high

Intuitively appealing, but wrong.

The two involved errors are hard to avoid, due to our experience in high base rate worlds: first, generating hypotheses based on evidence "usually works" in our causally organized experience, and second, p(Ej|Hi) often provides a good approximation for p(Hi|Ej). ACH does not warn the analyst about either of these errors. But the error most difficult to correct is failing to consider p(Ej|not Hi).

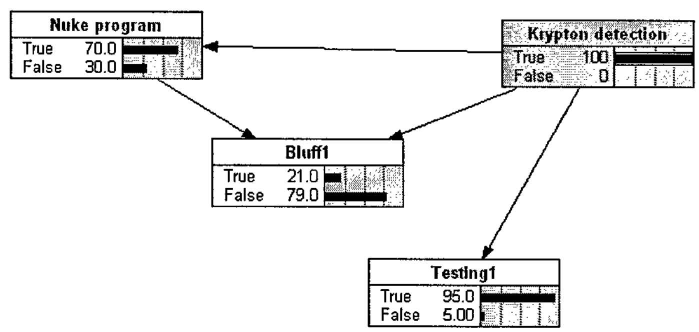

Figure 2: Bayesian belief network using p(H|E)

In our example, p(Ej| not Hi) is the probability of detecting Krypton gas when there is *no* enrichment activity. Depending on the situation, this probability might not be negligible. One common use of Krypton gas is insulation in double-pane windows. Another use is to test pipelines for leaks. If pipelines are common in the target country, then:

p(Krypton | not enrichment) = medium to high

We modeled this example in a Bayesian belief network (BBN), first by following the guidance of Jones (1998) and the Directorate of Intelligence (1987), *Deception Analysis Methodology*, as shown in Figure 2. Applying Bayes' rule with some representative numbers might lead one to determine that the detection of Krypton gas is not the definitive evidence one thought. A possible deception hypothesis is that the target might simulate a weapons-grade enrichment program, perhaps as an inexpensive deterrent to neighbors.

Observing Krypton in the first model (Figure 1) gives a high likelihood that there is a nuclear enrichment program, "Nuke program" (7:3 odds in favor of nuclear enrichment). A possible deception hypothesis, that that the target country might simulate a weapons-grade enrichment program by the intentional releasing Krypton, perhaps as an inexpensive deterrent to neighbors, is also shown, "Bluff1".[i] This model leads to a very low estimate of the probability of this possible deception (roughly 4 to 1 odds against deception). Notice also that the observation of Krypton leads to a very high likelihood of pipeline testing ("Testing1" 19:1 odds in favor).

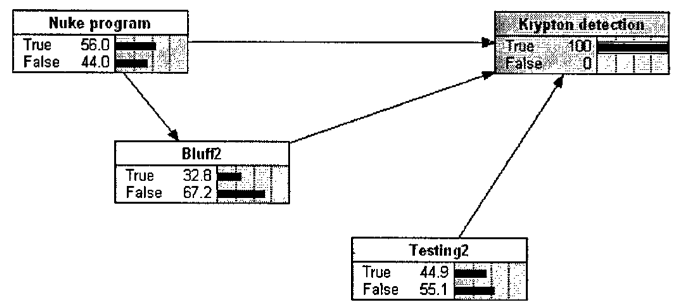

Figure 3: Bayesian belief network using p(E|H), i.e., normative reasoning.

Modeling the same ACH situation following Bayes's rule, i.e., *p(*E|H), and the same representative numbers (Figure 3) leads one to determine that the detection of Krypton gas is *not* a definitive indicator of uranium enrichment as suggested by the model in Figure 2. In the Bayes-based ACH BBN model, the observation of Krypton could indicate *either* nuclear enrichment *or* pipeline testing (roughly 50:50 odds), and the probability of the possible deception is considerably higher (2 to 1 odds against deception) than in the first ACH model (Figure 2, 4 to 1 odds against).

That is, by asking the Bayesian question, what is *p(*E|H); i.e., how likely am I to detect Krypton, given the three hypothetical causes: enrichment, bluffing, or pipeline testing; the analyst is less likely to over-estimate, or under-estimate, the likelihood of the hypotheses, compared to a *p(*H|E) implementation of ACH.[ii] In short, counter-deception analysts using ACH should consider the evidence and hypotheses following the Bayesian normative prescription, *p(*E|H), rather than the intuitive *p(*H|E) recommendation often found in the interpreters of Heuer's (1999) ACH method..

Summarizing, ACH offers a promising technique for counter-deception analysis, but some modification is needed so that hypothesis generation includes appropriate denial and deception COAs, and the ACH is used to elicit or estimate both *p(*Ej|Hi) and *p(*Ej| not Hi). We call our process, which is ACH with these modifications, "ACH-CD." The next section sketches how we partially automate ACH-CD for counter-deception decision support.

ACH-CD

ACH-CD extends Heuer's ACH process to do two things that are likely to be missed if one naively follows ACH. First, it incorporates *p(*E| not H) in elicitation and computation of the diagnostic impact of evidence. Second, it helps analysts consider deception hypotheses.

It is useful to distinguish two situations where counter-deception might be required. The first we call *tactical* counter-deception. Tactical situations are those where the adversary's goal is fairly obvious and the issue is detecting *how* he plans to accomplish that goal. Military operations and magic acts are examples of tactical counter-deception. We consider a situation one of *strategic* counter-deception when the issue at hand is *what* the adversary wishes to accomplish. Often in strategic situations, the adversary's course of action is unobservable or largely irrelevant to the main analysis.

Automating ACH-CD

We have developed two computer programs that partially automate ACH-CD. One technique (Elsässer and Stech 2003), is focused on tactical situations. It involves the following steps:

1. For a given situation, state one or more possible goal states.
2. Automatically generate hypotheses, in the form of state-based plans (courses of action), that can accomplish the goal state(s).
3. Automatically convert the course(s) of action (usually a contingency plan) to a Bayesian belief network.
4. Perform sensitivity analysis on the network by sequentially choosing possible outcome states and computing a factor of the optimal Bayesian dichotomizer (we omit the prior probability terms, as they are unnecessary and likely to be biased):

$$p(\mathrm{Ei}|\mathrm{H})/p(\mathrm{Ei}|\text{ not } \mathrm{H}), \text{ for all states Ei}$$

The log of the state odds ratios provides an indicator of the impact of each state on the probability of an outcome (hypothesis) of interest, ordered by time of potential observation. This yields three sets of time-state intervals, representing: the states that must be hidden (denied), observations that have no probative value to the observer, and the states that one might simulate to deceive an adversary. Importantly, the list often will include negative information – states that are highly informative if one does NOT observe them. Reasoning about negative evidence is particularly problematic for people.

The counter-deception analyst can use these results to direct collection to the most probative evidence. By knowing which states (observations) have no probative value, one can avoid the confirmation bias, basically seeing everything as support for one's preconceived notions about the adversary's intent. A deception planner can use the results of this system to determine which observations must be denied or have a plausible cover story. Strong indicators of an alternative hypothesis might be simulated to mislead the adversary.

Our second process is aimed at strategic deceptions that do not have a strong course of action analysis component, such as the question "does Iran have a nuclear weapons program?" This process starts with the elicitation of a set of mutually exclusive hypotheses, stated as True/False propositions. We automatically include a non-informative hypotheses, labeled "Other," so the list is exhaustive. This is followed by eliciting the items of evidence that are available. The most time consuming step is eliciting from the analyst(s) estimates of $p(Ei|Hj)$ and $p(Ei|$ not $Hj)$ for all evidence Ei and hypothesis Hi. In practice, many of the elements of evidence will be uninformative (50-50) for some of the hypotheses.

After the elicitation, a Bayesian belief network is created and the sensitivity analysis process described above is performed. The result is a list of evidence states that, if observed, would have the most significant impact on the likelihood of a given hypothesis.

The remainder of the paper describes how the Japanese Navy might have used the first of these methods, the ACH and ACH-CD counter-deception evidence elicitation and evaluation procedures, to improve their counter-deception assessments of American courses of action prior to the Battle of Midway.

APPLYING ACH TO MILITARY COUNTER-DECEPTION

We illustrate how ACH-CD can address military counter-deception by examining the Japanese planning for the Battle of Midway from the viewpoint of the Imperial Japanese Navy (JN). In planning for this operation the JN conducted war plan reviews, table-top exercises, and naval exercises which shared the same steps as Heuer's ACH, but as disjointed planning episodes, not as an integrated analytic process, as Heuer advocates. Many of the tactical and operational problems that contributed to the defeat of the JN at Midway were specifically identified and discussed during these JN ACH-like exercises, but the Japanese planners ultimately dismissed the identified problems, or met them with inadequate half-measures or inappropriate ripostes. As JN planning assumptions were shown to be incorrect during the operation itself, the JN failed to replan or adjust its operations.

JN Planning Hypotheses (explicitly surfaced by the JN before the battle in ACH-like exercises):

- *H1:* U.S. Pacific Fleet would respond to the JN invasion of Midway, sending its remaining aircraft carriers (CVs) to attempt to retake Midway.
- *H2*: U.S. Pacific Fleet would *not* respond to the JN invasion of Midway; letting Japan extend its naval base perimeter to mid-Pacific.
- *H3:* U.S. Pacific Fleet aircraft carriers will be waiting near Midway to attack the JN Carrier Battle Group *(Kido Butai)*.

The JN received considerable intelligence and had operational and tactical experience before the Battle of Midway that was relevant to assessing these three hypotheses (see Appendix 1 and sources). While historical accounts strongly indicate that the JN surfaced these hypotheses explicitly in its ACH-like exercises, the record is clear that the JN never made an integrated attempt to consider *all* the evidence and *all* of the hypotheses as advocated by Heuer's ACH method. That is, the hypotheses were raised and considered episodically and evidence was dismissed piece-meal. The JN planners never considered all the evidence against these hypotheses as they assessed the strengths and weaknesses of their planning assumptions. Much of the evidence reflecting JN tactical and operational weaknesses (e.g., in intelligence, reconnaissance and surveillance, ISR) was largely ignored in the design of "Operation MI." In short, the JN neither organized an assessment of all the intelligence and evidence in planning Operation MI, nor acknowledged the impact of important evidence that reflected potential problems in executing the plan.

Had the JN simply drawn tentative conclusions using Heuer's ACH technique (see Table 1, top), that is, assessed the relative likelihood of each hypothesis based on the evidence they had available, $p(H_j|E_i)$, the JN might have estimated that it was perhaps as likely the U.S. Pacific Fleet carriers could be waiting to ambush the *Kido Butai* (H3), or that the U.S. carriers would *not* respond as the JN intended to Operation MI (H2), as was the hypothesis that the U.S. would respond as the JN assumed to the invasion of Midway (H1).

Had the JN assessed the evidence using the ACH-CD manner we recommend (see Table 1, bottom), that is, assessing the relative likelihood that the evidence would be observed given each of the hypotheses ($p(E_i|H_j)$ and $p(E_i|\text{ not } H_j)$), the JN might have concluded that H2 *and* H3 were as likely as H1, and that the available evidence did *not* strongly support the JN favored COA, H1.

Table 1: Evaluating JN Hypotheses			
	ACH: Evaluating JN Hypotheses against Evidence (likelihood of hypotheses in light of evidence): $p(H_j\|E_i)$ [See Appendix 2]		
Likelihoods	***H1:* U.S. will respond to JN invasion of Midway**	***H2*: U.S. will *not* respond to JN invasion of Midway**	***H3:* U.S. will be waiting near Midway**
Evidence Items In Favor	9	7	10
Evidence Items Opposed	9	6	7
Evidence Items Uncertain	0	5	1
Likelihoods	**ACH-CD: Evaluating JN Evidence against Hypotheses (likelihood of evidence in light of hypotheses): $p(E_i\|H_j)$ & $p(E_i\|\text{ not } H_j)$ [See Appendix 3]**		
Evidence Items In Favor	8	9	9
Evidence Items Opposed	9	8	7
Evidence Items Uncertain	1	1	2

In other words, the JN might have done much to overcome the first two major hurdles impairing their counter-deception analysis: *Poor anomaly detection* (missing anomalies or prematurely dismissing anomalies as irrelevant or inconsistent) and *Misattribution* (attributing inconsistent or anomalous events to collection gaps or processing errors, rather than to deception); had the JN used the ACH and/or the ACH-CD methods of assessment of the evidence and the hypotheses that had been surfaced at the various JN ACH-like exercises. Using either ACH or ACH-CD to review the JN planning assumptions against the available evidence, the JN planners would have had ample reason to re-examine the soundness of "Operation MI."

Futhermore, the JN might have been able to overcome the third major impediment to effective counter-deception analysis: *Failure to link deception tactics to deception* *hypotheses* (failure to recognize anomalous evidence as indicators of deception). That is, the events and evidence available to the JN before the Battle of Midway might have been assessed as possible indicators that the U.S. Pacific Fleet was using denial and deception tactics to conceal its true response to "Operation MI." Evidence reflecting specific denial and deception tactics used to conceal H2 or H3, and inconsistent with H1, are shown in Tables 2 and 3. Note that these indicators included negative evidence (e.g., *No U.S. aircraft carriers sightings in South Pacific after 17 May 1942; No apparent objectives for U.S. carriers in South Pacific, late May 1942*).

Table 2: Counter-Denial Indicators Available to JN Before the Battle of Midway

Denial Tactics	***Features of Denial Tactics***	***General Indicators of Denial Tactics***	***Indicators from Battle of Midway, May-June 1942***
Masking	Hide & conceal key characteristics, while matching another; eliminate characteristic patterns, blend characteristics with background patterns	--Key components missing, incomplete, or unaccounted; --High information value components unobserved where expected	- U.S. aircraft carriers undetected in North Pacific vicinity Hawaii or Midway, until 1-3 June 1942 - Aerial surveillance aircraft vicinity Midway all shot down
Repackaging	Add and change key characteristics; modify characteristic patterns, match an alternative component's characteristic pattern	--Excessive, inconsistent, or unexpected alternative components detected; --Too many of the wrong things	- U.S. aircraft carriers radio traffic prevalent in South Pacific - Operation K thwarted - Midway defenses & reconnaissance greatly enhanced, 3-4 Jun 1942 - Aleutian, other N. Pacific defenses *not* enhanced
Dazzling	Obscure key characteristics, saturate perception by adding over-powering characteristics; blur characteristic patterns to increase observer uncertainty	--Unexpected perceptual stimuli; --Atypical or uncommon patterns; --Unusual intensity, density, frequency	- Apparent U.S. carrier losses, e.g., Battle of Coral Sea - No apparent objectives for U.S. carriers in South Pacific, late May 1942.
Red Flagging	Display key characteristics ostentatiously, make high information value patterns conspicuously obvious, "wave a red flag;" generate observer suspicions	--Some, but not all, expected key components on obvious display; --Significant key components missing or unaccounted for	- U.S. submarines and scout aircraft at Midway deployed beyond normal operational limits, 1-3 June 1942. - U.S. aircraft carriers undetected in North Pacific vicinity Hawaii or Midway, until 1-3 June 1942

Table 3: Counter-Deception Indicators Available to JN Before the Battle of Midway			
Deception Tactics	***Features of Deception Tactics***	***Indicators of Deception Tactics***	***Indicators from Battle of Midway, May-June 1942***
Mimicking	Recreate or imitate a familiar characteristic patterns; copy alternative characteristics; create fictitious entities	--Observations inconsistent with expected numbers, patterns, configurations --Insufficient fidelity, inexplicable anomalies --Too many of the wrong thing	- U.S. aircraft carriers radio traffic prevalent in South Pacific - No U.S. aircraft carriers sightings in South Pacific after 17 May 1942 - No apparent objectives for U.S. carriers in South Pacific, late May 1942.
Inventing	Create new characteristic patterns with high information value; synthesize realistic indicators; invent key components	--Insufficient history, resolution, fidelity --Multi-dimensional "thinness" --Inappropriate consistencies --Exploitation of expectations, conditioning, reflexive control	- U.S. aircraft carriers radio traffic prevalent in South Pacific - No U.S. aircraft carriers sightings in South Pacific after 17 May 1942 - "Midway short on water"—"AF" short on water
Decoying	Create parallel characteristic patterns forming immaterial entities or indicators; provide realistic characteristic patterns to increase observer certainty	--Insufficient history or contiguity --Configuration & correlation anomalies --Multi-spectral anomalies or resolution "thinness" --Inconsistencies in spectral or dimensional resolution	- No apparent objectives for U.S. carriers in South Pacific, late May 1942. - U.S. aircraft carriers undetected in North Pacific vicinity Hawaii or Midway, until 1-3 June 1942
Double Play	Weakly & suspiciously suggest correct interpretation to reinforce incorrect interpretation; maintain or display real but suspicious characteristics to decrease observer acceptance	--Inconsistent history or timing of discrediting information --Discontinuous volume or intensity of disconfirming information --Inconsistent selectivity of information --Artificial consistency or uniformity of discrediting information	- U.S. radio traffic in North Pacific vicinity Hawaii, 1-3 June 1942

We put this evidence of possible deception into a Bayesian belief network and linked the evidence to the relevant events (e.g., U.S. CVs in SW Pacific, US CVs in NW Pacific, Midway Island defenses enhanced, see Figure 4). We set the prior probabilities at H1= 70%, H2 = 20%, H3 = 9%, and H4 (Other) = 1%. We linked the events and hypotheses to the evidence using the ACH-CD procedures described above, using intermediate probabilities representative of a counter-deception analyst's expectation of events (e.g., US CVs in SW Pacific) and associated intelligence evidence items (US CVs SIGINT), given those events (True and False) and those COAs (Intercepted, Not Intercepted). The likelihoods connecting the intelligence evidence to the relevant events and to the hypotheses reflects the possibility of American denial and deception. That is, the JN counter-deception analyst should reason that, if *H3* were TRUE, but event *US CVs in SW Pacific* is FALSE, *US CVs SIGINT* INTERCEPTED would very likely (p=.8), because such American radio deception would be consistent with H3.

The evidence indicating possible denial and deception tactics is instantiated, as shown in Figure 5 by the gray boxes. For example, SIGINT intercepts indicated the US aircraft carriers (CVs) in the Southwest Pacific (SW Pac). JN ISR sighted U.S. CVs in SW Pac on 17 May, but not after. Midway Island aerial and submarine reconnaissance ranges were increased from 500 miles to 700 miles (MI_Recce_Expanded). The impact of these denial and deception indicators on the hypotheses reflecting the enemy COAs is dramatic. In Figure 5, the probability of H1 drops from 70% to about 14%, while H3 jumps from 9% to over 85%.

The role of H4: Other

H4: Other in these models provides an index of noise versus signal in the interpretation of the intelligence. All the intelligence relative to H4 is coded as $p(Ei|\text{ H4}) = p(Ei \mid \text{not H4}) = .50$. That is, since the evidence cannot discriminate between H4 and its opposite not H4, the likelihood of H4 represents a baseline of complete ignorance relative to the other hypotheses H1—H3. When all the intelligence is noise, the likelihood of H4 approaches 1.0. In our models, with the benefit of hindsight, all the intelligence evidence is "pure signal" and can be interpreted to have discriminatory significance for the H1 – H3 hypotheses. Had more noisy intelligence been added to these models, the strength of H4 would increase, but the likelihoods of H1—H3 relative to each other would remain in the same relative proportions. That is, the models would still reflect that the "pure signals" would indicate the possibility of American denial and deception tactics and the possibility of H2 and H3 as well as H1.

While the effect shown in Figure 5 is powerful, it merely shows the impact of isolating the intelligence evidence that was most indicative of possible American denial and deception tactics and then determining how that evidence could impact beliefs in possible enemy COAs. That is, the model shown in Figures 4 and 5 might have been used by a JN counter-deception analyst to make the case that the success of Operation MI was highly sensitive to indicators that JN intelligence had noted of possible American denial and deception. Such indicators strongly support the possibility of COA H3, an American ambush. Although JN intelligence had observed the indicators of American denial and deception tactics, the Japanese lacked the framework and business process that allows these indicators to be linked to hypotheses of deceptive COAs.

In making an overall assessment of the JN intelligence, all key intelligence items should be weighed along with these denial and deception indicators, in keeping with the ACH-CD procedure. Bayesian belief networks based on all the events, intelligence, and evidence available to the JN prior to the battle (Appendix 1) is shown in Figure 6, with the linking probabilities set using our ACH-CD process, with the prior probabilities for H1 through H4 as before. When all these evidence items are instantiated, as they might have been on the eve of the battle, the probabilities for the enemy (U.S. Pacific Fleet) COAs change dramatically (Figure 7, Table 4).

Table 4: Probabilities for Enemy Courses of Action before and after evidence available to JN before the Battle of Midway is considered using ACH-CD process.

Enemy (U.S. Pacific Fleet) Courses of Action	***Notional Prior Probability [Figure 6]***	***Probability after evidence is considered [Figure 7]***
H1: U.S. Pacific Fleet would be surprised, and would respond to the JN invasion of Midway, sending its remaining aircraft carriers to attempt to retake Midway.	70%	<2%
H2: U.S. Pacific Fleet would be surprised, and would *not* respond to the JN invasion of Midway; letting Japan extend its naval base perimeter to mid-Pacific.	20%	<1%
H3: U.S. Pacific Fleet would *not* be surprised, and its carriers will be waiting near Midway to attack the JN Carrier Battle Group (*Kido Butai).*	9%	98%
H4: Other COA	1%	<1%

Additionally, if the evidence available to the JN in April, May, and through 3 June 1942 are instantiated in the Bayesian belief network, the changing probabilities (Table 5) reflect how the accumulating intelligence might have shifted JN beliefs in the various enemy COAs in response to "Operation MI."

Table 5: Probabilities for Enemy Courses of Action based on evidence available to JN in April, May, and up to 3 June 1942.

Enemy (U.S. Pacific Fleet) Courses of Action	***April 1942***	***May 1942***	***3 June 1942***
H1: U.S. Pacific Fleet would be surprised, and would respond to the JN invasion of Midway, sending its remaining carriers to attempt to retake Midway.	69%	29%	<2%
H2: U.S. Pacific Fleet would be surprised, and would *not* respond to the JN invasion of Midway; letting Japan extend its naval base perimeter to mid-Pacific.	20%	1%	<1%
H3: U.S. Pacific Fleet would *not* be surprised, and its carriers will be waiting near Midway to attack the JN Carrier Battle Group (*Kido Butai).*	10%	70%	98%
H4: Other COA	1%	<1%	<1%

The pattern in Table 5, the possible JN appreciation of alternative U.S. Navy COAs, is symmetrical with the growing understanding of Japanese plans and intentions by the Pacific Fleet intelligence officers and commanders in Hawaii. By the end on May 1942, they had pieced together 90% of the plans for "Operation MI," had successfully portrayed the remaining US carriers as being in the Southwest Pacific through radio deception, and had planned their ambush for the Japanese carriers. When the *Kido Butai* arrived at Midway, the rest, as the saying goes, is history. Had the Japanese had better counter-deception business processes, their situation assessment might not have been so far inferior to that of their opponent, and the outcome might not have been so one-sided.

Taken as a whole, both the ACH and ACH-CD techniques, which showed that H2 and H3 could not be ruled out as American COAs, and that H1, the enemy COA that the JN used as the basis for Operation MI was merely possible, not highly probable, as the JN planners believed. When denial and deception indicators are identified and considered in the Bayesian belief network, the impact of this intelligence on the probability of H3 is dramatic, and the possibility of an American deception and ambush becomes extremely difficult to ignore. Using a counter-deception business process to evaluate the sensitivity of possible enemy COAs to all the available evidence could have aided the JN planners to track the American deception and perhaps to avoid the utter debacle of "Operation MI."

In summary, the JN operational planners and intelligence analysts might have used Heuer's ACH, or our ACH-CD process, to review the available evidence and the planning assumptions underlying "Operation MI," as well as the other COA hypotheses that were surfaced in the JN ACH-like exercises. Using the ACH technique, they might have noted that the evidence available before the Battle of Midway was just as consistent with H3, the deception hypothesis (the U.S. Pacific Fleet would ambush the JN attack) as it was with H1, the hypothesis on which "Operation MI" was based (that the Pacific Fleet would be surprised by Operation MI and would respond on the JN time-table).

Furthermore, had the JN compared this evidence to general indicators of denial and deception tactics, they might have noted further support for the hypothesis that the U.S. Navy would not be surprised by Operation MI and was using denial and deception to cover its riposte.

Had the JN planners used tools such as we developed to support a counter-deception business process, they would have been able to isolate those items of evidence that were most significant in supporting the various possible U.S. COAs. These sensitivities can reinforce ISR operations and counter-planning; e.g., could have aided the JN in the design of planned or natural operational-intelligence "experiments," as recommended by R. V. Jones's "theory of spook unmasking," to force the U.S. Pacific Fleet to reveal more evidence of its intentions and dispositions. For example, a realistic JN feint in the Coral Sea towards New Guinea or Australia in late May 1943 might have forced the U.S. Navy to react and thus uncovered Nimitz's radio deception.

CONCLUSIONS AND AREAS FOR FURTHER RESEARCH

We have demonstrated how a counter-deception business process based on ACH-CD can be applied to military counter-deception. We showed how evidence available to the Japanese Navy prior to the Battle of Midway, if analyzed using ACH-CD, might have aided detection of the American deception that allowed the U.S. Pacific Fleet carriers to surprise and ambush the Japanese carriers threatening Midway Island.

We have developed a software system that automates ACH-CD. Our effort now is on extending the core ACH-CD process to deal with the issue of "local versus global deception," and the generation of more complex courses of action. We are reviewing ongoing research on algorithms that detect anomalies to incorporate in our counter-deception business process and tools (e.g., Dragoni 1996, Johnson 2004, Santos 2004, Sarter et al. 1997].

We are building an interface to our deception planning system that will help users easily create realistic domain descriptions. The deception planning system will fill in these plans and create COAs as alternatives. On the back end, the planning system suggests deception tactics to keep an adversary from recognizing the true plan (dissimulation) and ways to give the adversary a false apprehension of reality (simulation). A temporal model generated with the alternate courses of action will be an important input to this process. The deception planning system will be extended to counter-deception planning using AP's counter-planning process.

We have been conducting experiments to assess how well our counter-deception business process can reliably (a) plan deceptions, and (b) detect deceptions. As indicated above, the system has been successful in determining previously unknown details of how historic deceptions have succeeded, such as the Battle of Midway, and in reflecting how better assessment of intelligence using a counter-deception business process can increase the likelihood of detecting and characterizing deceptions.

ACKNOWLEDGEMENTS

The research reported in this paper is sponsored by The MITRE Corporation. All opinions expressed are those of the authors and not of the MITRE Corporation. Approved for public release; distribution unlimited, MITRE Case Number 04-0813.

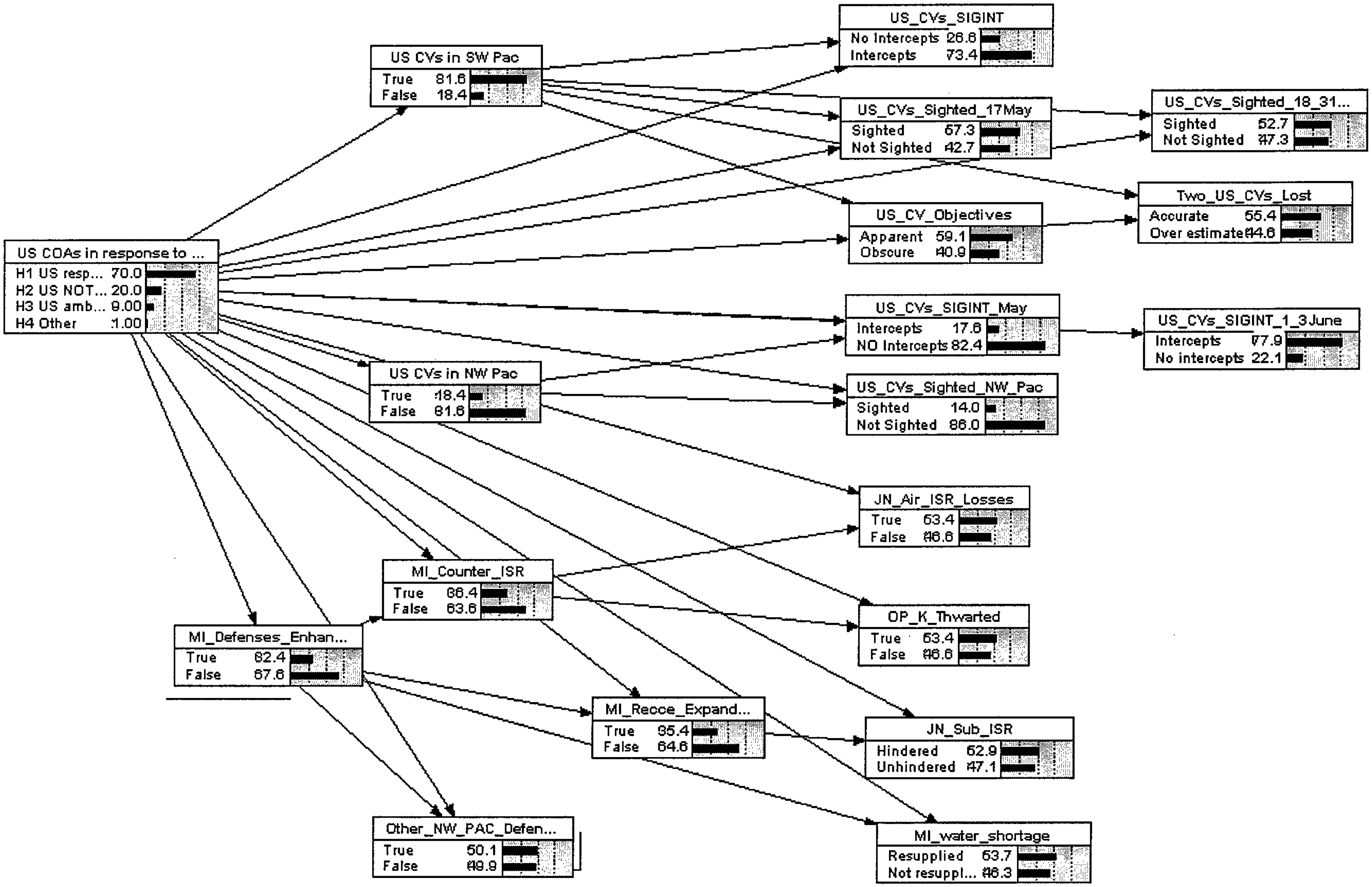

Figure 4: Bayesian belief network reflecting events (center) related to Japanese hypotheses (left, enemy courses of action, COAs, H1—H4) in response to "Operation MI" and available intelligence evidence (right) of possible American denial and deception tactics linked to those COAs and events.

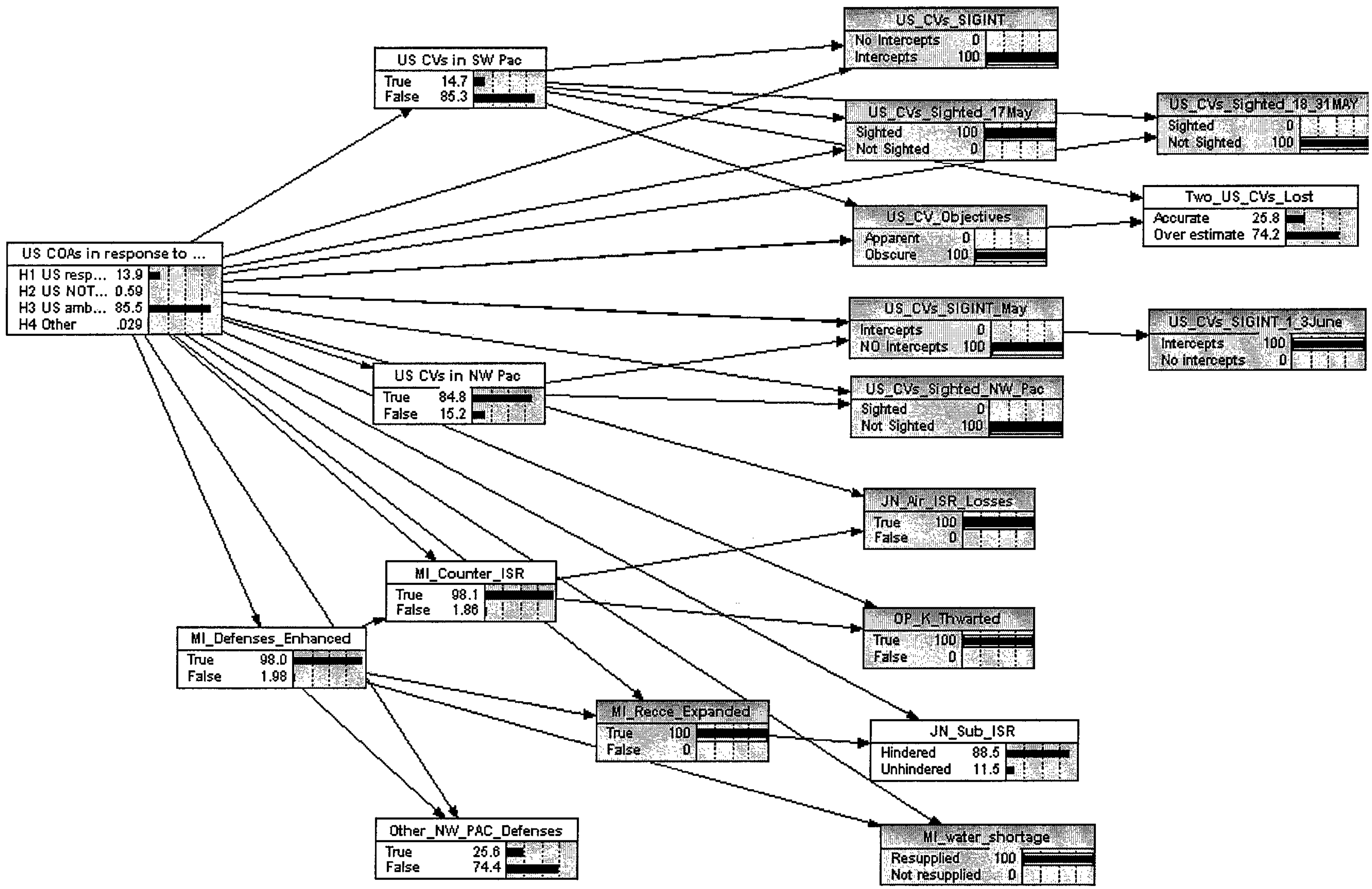

Figure 5: When evidence of possible denial and deception (gray boxes), observed by the JN prior to the Battle of Midway, is instantiated in the Bayesian belief network, it strongly supports enemy COA *H3:* U.S. Pacific Fleet would *not* be surprised, and U.S. carriers will be waiting near Midway to ambush the JN Carrier Battle Group (*Kido Butai*).

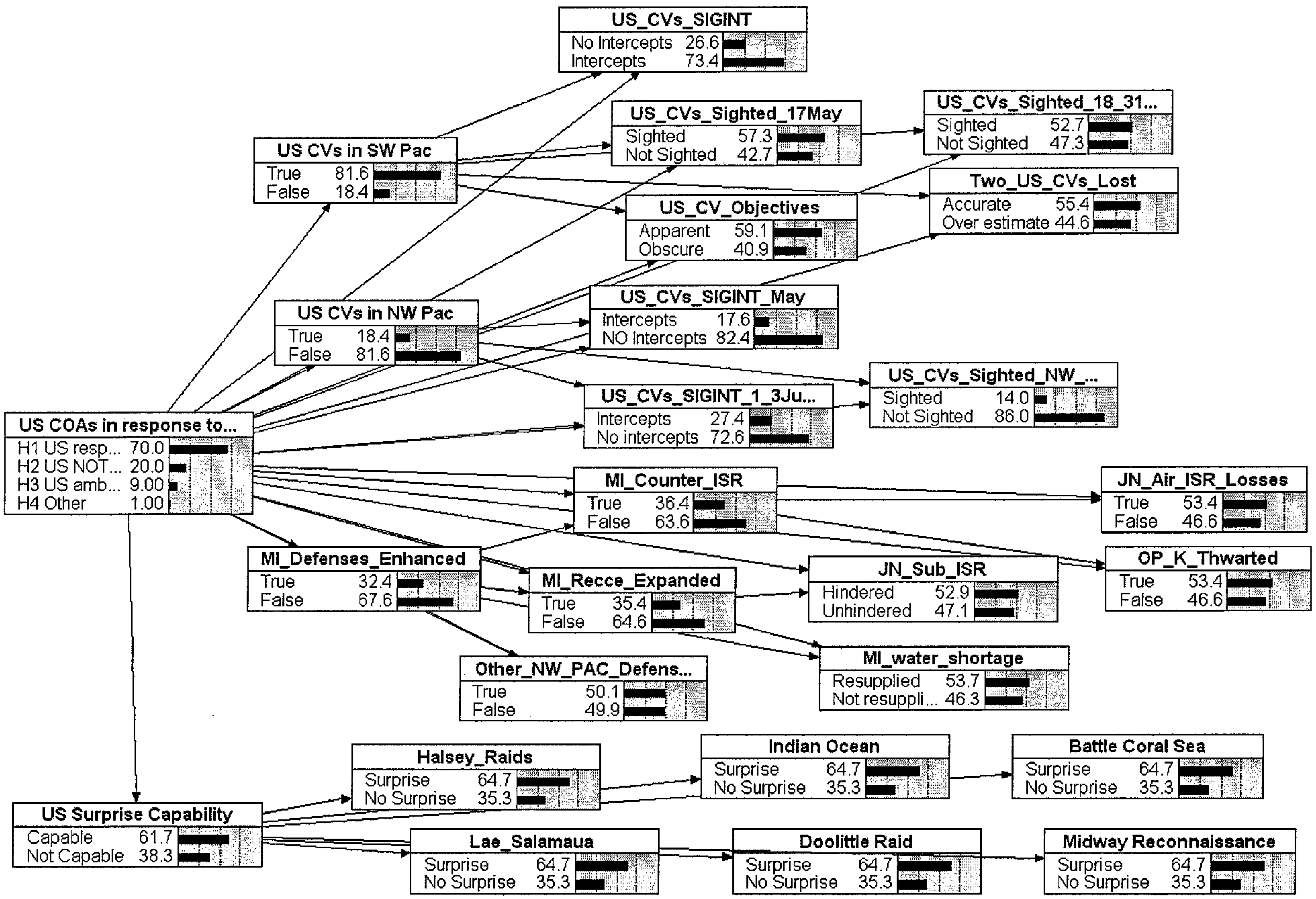

Figure 6: Bayesian belief network showing the events, intelligence, and evidence obtained by Japanese Navy before Battle of Midway (based on Appendix 1) and prior probabilities for enemy (US) COAs, favoring COA H1: U.S. Pacific Fleet would be surprised, and U.S. carriers would respond to Japanese attack on Midway Island.

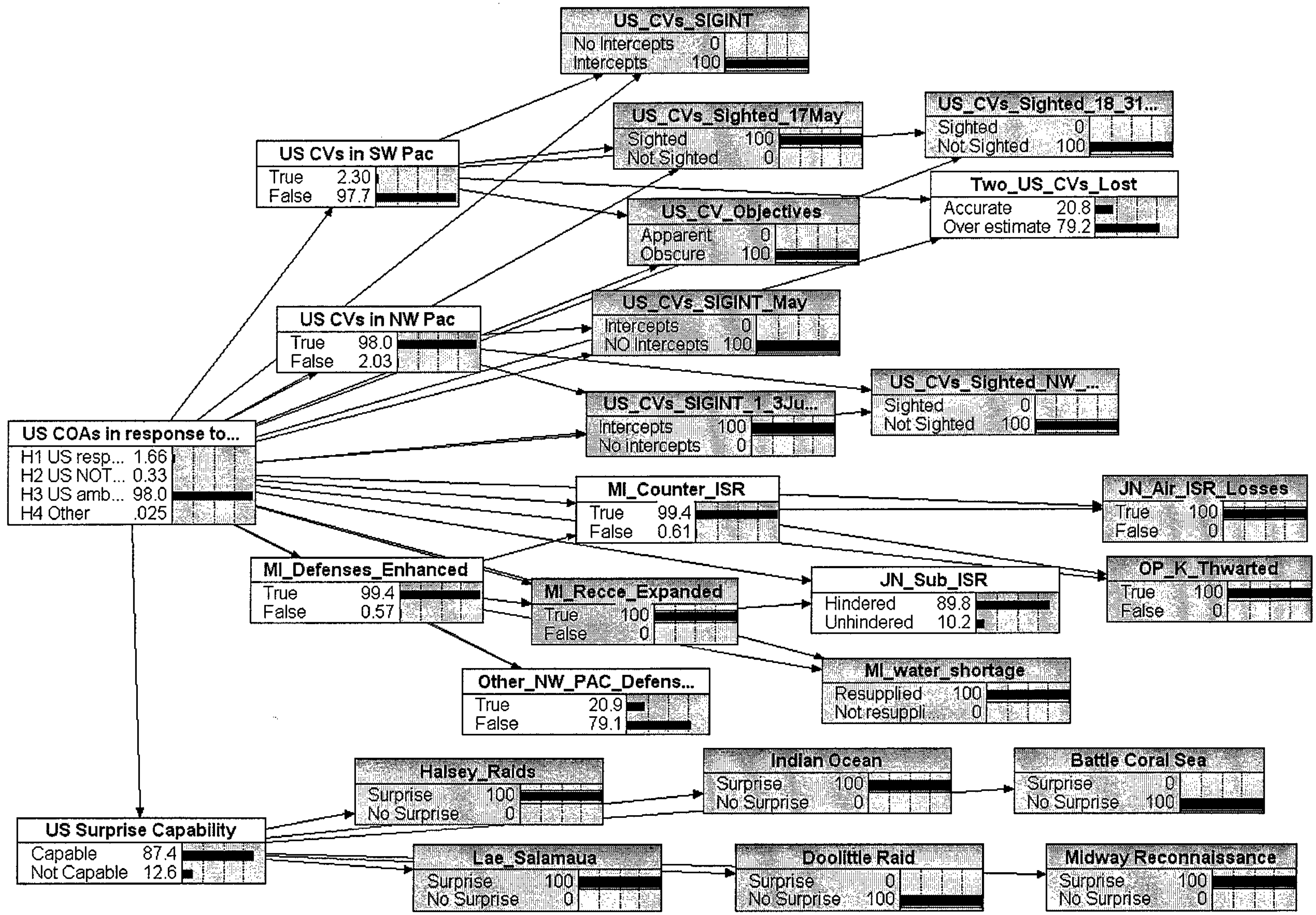

Figure 7: When evidence, observed by the JN prior to the Battle of Midway (gray boxes), is instantiated in the Bayesian belief network, it strongly supports enemy COA *H3:* U.S. Pacific Fleet would *not* be surprised, and U.S. carriers will be waiting near Midway to ambush the JN Carrier Battle Group (*Kido Butai*).

References

Burns, K. (2004a) "Mental Models and Normal Errors", in H. Montgomery, R. Lipshitz and B. Brehmer, Eds., *How Professionals Make Decisions*, Lawrence Erlbaum Associates.

Burns, K. (2004b) "Bayesian Boxes: A Colored Calculator for Picturing Posteriors", *Proceedings of the Third International Conference on the Theory and Application of Diagrams,* Cambridge, UK, March 22-24 (2004).

Burns, K. (2004c) "Painting Pictures to Augment Advice", *Proceedings of the Seventh International Working Conference on Advanced Visual Interfaces,* Gallipoli, Italy, May 25-28 (2004).

Dawes, Robyn M. (2001) *Everyday irrationality: how pseudo scientists, lunatics, and the rest of us systematically fail to think rationally.* Westview Press, Boulder, Colorado.

Directorate of Intelligence (1987) *Deception Analysis Methodology: A Reference Aid,* CIA, DI Reference Aid.

Dragoni, A. F (1996) "Maximal Consistency, Theory of Evidence and Bayesian Conditioning in the Investigative Domain;" *Proceedings of the Fifth Iberoamerican Confernece on Computer Science and Law,* Havana. 1996.

Gigerenzer, Gird, Peter M. Todd, and the ABC Research Group (1999), *Simple Heuristics that Make Us Smart,* Oxford University Press, New York.

Gilovich, Thomas, D. Griffin, and D. Kahneman (2002) *Heuristics and Biases* Cambridge University Press, Cambridge, United Kingdom.

Heuer, Richards J. Jr. (1981), "Strategic Deception and Counterdeception: A Cognitive Process Approach," *International Studies Quarterly,* Vol. 25, No. 2, 294-327.

Heuer, Richards J. Jr. (1999) *Psychology of Intelligence Analysis.* Washington: Central Intelligence Agency Center for the Study of Intelligence.

Johnson, Paul E., S. Grazioli, K. Jamal, and R. G. Berryman (2001) "Detecting deception: Adversarial problem solving in a low base-rate world," *Cognitive Science* 25(3), May-June.

Johnson, Gregory and Santos, Eugene, Jr., ``Deception Detection in Information Systems I: Activation of Deception Detection Tactics,'' Proceedings of AI 2004, 339-354, London, Ontario, Canada, 2004.

Jones, R. V. (1978) *The Wizard War: British Scientific Intelligence, 1939-1945.* New York: Coward, McCann, and Geoghegan.

Jones, R. V. (1989) *Reflections on Intelligence.* London: Mandarin.

Jones, R. V. (1995) "Enduring principles: Some Lessons in Intelligence," *CIA Studies in Intelligence*, 1995, Volume 38, Number 5. http://www.cia.gov/csi/studies/95unclass/Jones.html

Santos, Eugene, Jr. and Johnson, Gregory (2004) "Toward Detecting Deception in Intelligent Systems,'' to appear in *Proceedings of the SPIE: Defense & Security Symposium*, Vol. 5423, Orlando, FL.

Sarter, N.B., D. D. Woods, and C.E. Billings, (1997) "Automation Surprises," Handbook of Human Factors & Ergonomics, second edition, G. Salvendy (Ed.), Wiley.

Whaley, Barton and J. Busby (2002), "Detecting Deception: Practice, Practitioners, and Theory" in Roy Godson and James J. Wirtz (Editors.), *Strategic Denial and Deception: The Twenty-First Century Challenge*. New Brunswick: Transaction Publishers.

Appendix 1

Events, Intelligence, And Evidence Obtained by JN Before the Battle of Midway	
Date	*Events and evidence*
Jan-Mar 1942	U.S. carrier raids against the Marshalls, Rabaul, Wake, Marcus Island, and eastern New Guinea: Indicates ineffectiveness of JN reconnaissance and warning intelligence.
10 Mar 1942	U.S. carrier aircraft surprise ADM Kajioka's Japanese Landing Forces at Lae and Salamaua in the Solomon Sea: U.S. carriers able to position themselves to ambush the JN landing forces and escape. Indicates effectiveness of U.S. intelligence and reconnaissance.
2-5 Apr 1942	Naval General Staff and Combined Fleet Planning Debate: JN war-gamers assumed U.S. forces would conform to JN plan and timetable (H1). No efforts to war-game a delayed U.S. response, after Japanese fleet had departed (H2). No efforts to war-game U.S. surprise at Midway (H3). No JN estimates of possible impacts of a U.S. victory (or draw) at Midway on U.S. or Japanese strategy, operations, or morale. Indicates narrow assumptions governing JN planning.
5-9 Apr 1942	*Kido Butai* Surprised in Indian Ocean: Detected by land-based reconnaissance and bomber aircraft, and surprised by British cruisers DORSETSHIRE and CORNWALL, carrier HERMES and destroyer VAMPIRE. Indicates weak JN carrier-based counter-surveillance, intelligence, and reconnaissance.
18 Apr 1942	Sharp increase in U.S. Navy radio communications near homewaters: JN traffic analysis correctly indicate Doolittle Raid.
1-6 May 1942	Combined Fleet War Games: raise the contingency that U.S. carrier task force might appear on *Kido Butai* flank during scheduled air attack on Midway: JN umpire negates effective contingency response planning.
31 May - 3 Jun 1942	U.S. units occupying French Frigate Shoals: Operation K forestalled (plan for JN subs to rendezvous at French Frigate Shoals to refuel seaplanes flying from Wotje, to reconnoiter Pearl Harbor)
7-9 May 1942	JN SIGINT: detected U.S. carrier force in the Coral Sea prior to Operation MO--Battle of the Coral Sea.
7-9 May 1942	JN report both U.S. carriers (LEXINGTON and YORKTOWN) sunk in Battle of the Coral Sea: JN Naval Staff assumes U.S. has two remaining carriers (HORNET and ENTERPRISE).
15-16 May 1942	JN air reconnaissance: Identifies HORNET and ENTERPRISE in Solomons Islands.
May-3 Jun 1942	JN COMINT: Identifies HORNET and ENTERPRISE radio communications in South Pacific. JA Naval Staff concludes U.S. has not detected JN Midway intentions (Operation MI).
18-20 May 1942	JN COMINT: Reports Midway radio indicates island short on water, Hawaii will re-supply.
May 1942	JN Air Reconnaissance: All long-range Japanese aerial reconnaissance missions to Midway are destroyed.
24 May 1942	JN Combined Fleet Estimate: At final Table-top Maneuvers ADM Ugaki (Yamamoto's Chief of Staff) states: "It is hard to make accurate judgment of the next enemy move…but according to newspapers they were reported to be heading for Australia. At present, the whereabouts of two enemy carriers is unknown—either in Australia or Hawaii." Failure to include all possible hypotheses (e.g., H3).
24 May 1942	JN Combined Fleet Estimate: JN intelligence on Aleutians was abysmal, out-of-date, vastly over-estimating U.S. ground forces, under-estimating naval forces, and completely ignorant of land-based air forces.

Events, Intelligence, And Evidence Obtained by JN Before the Battle of Midway	
Date	*Events and evidence*
29-31 May 1942	JN Reports: U.S. reconnaissance arc extended from 500 to 700 miles from Midway. U.S. submarine transmission indicated JN Transport Group had been discovered west of Midway. U.S. Pacific Fleet radio traffic and ratio of urgent messages greatly increased in Hawaiian and Alaskan waters: JN indications of U.S. readiness and preparedness for Operation MI.
2 Jun 1942	*Kido Butai* failed to receive urgent transmission: JN Naval Staff estimates that Americans had discovered Midway operation and might be sending carriers to ambush *Kido Butai.*
3 Jun 1942	*Kido Butai* estimate: "It is not believed that the enemy has any powerful unit, with carriers as its nucleus, in the vicinity."
3 Jun 1942	U.S. Midway-based PBY scout aircraft: Spot JN Invasion Force where predicted (24 hours before Japanese expected to be detected).
0820 4 Jun 1942	JN Scout aircraft: Reports U.S. carriers within 150 miles of *Kido Butai.*
1024 4 Jun 1942	U.S. carrier dive bombers sink three *Kido Butai* carriers within minutes, later sink fourth.

Primary Sources: Henry F. Schorreck, Department of the Navy, Naval Historical Center, *Battle of Midway: 4-7 June 1942: The Role of COMINT in the Battle of Midway (SRH-230),* 12 April 1999. Frederick D. Parker, "A Priceless Advantage: U.S. Navy Communications Intelligence and the Battles of Coral Sea, Midway, and the Aleutians," *United States Cryptologic History, Series IV, World War II, Volume 5,* Center For Cryptologic History, National Security Agency, 1993. www.centurytel.net/midway/priceless/. Department of the Army, *Pearl Harbor Operations: General Outline of Orders and Plans, Japanese Monograph No. 97*, Office of the Chief of Military History, 19 February 1953. www.ibiblio.org/pha/monos/097/index.html. ADM Chester Nimitz, *Battle of Midway: 4-7 June 1942, Online Action Reports: Commander in Chief, Pacific Fleet, Serial 01849 of 28 June 1942.* Department of the Navy -- Naval Historical Center http://www.history.navy.mil/docs/wwii/mid1.htm. Mitsuo Fuchida and Masatake Okumiya, *Midway: The battle that doomed Japan.* New York: Ballantine Books, 1955. Masatake Okumiya and Jiro Horikoshi with Martin Caidin, *Zero! The story of Japan's Air War in the Pacific: 1941-45.* New York: Ballentine, 1956. Department of The Navy, Naval Historical Center, *The Japanese Story of the Battle of Midway* (*A Translation*) OPNAV P32-1002 Office of Naval Intelligence, United States Navy, June 1947. http://navylibrary.nhc.navy.mil/. Edwin T. Layton, with Roger Pineau and John Costello, *"And I was there:" Pearl Harbor and Midway--breaking the secrets.* New York: W. Morrow, 1985. Donald M. Goldstein and Katherine V. Dillon (eds.), *Fading Victory: The Diary of Admiral Matome Ugaki, 1941-45.* Pittsburgh, PA: University of Pittsburgh Press, 1991. W. J. Holmes, *Doubled-Edged Secrets: U.S. naval intelligence operations in the Pacific during World War II.* Annapolis, MD: Naval Institute Press, 1979. Edward van der Rhoer, *Deadly MAGIC: A Personal Account of Communications Intelligence in World War II in the Pacific.* New York: Charles Scribner's Sons, 1978. F. H. Hinsley and Alan Stripp, *Codebreakers: The Inside Story of Bletchley Park.* Oxford: Oxford University Press, 1993.

Secondary Sources: Gordon W. Prange, Donald M. Goldstein, and Katherine V. Dillon, *Miracle at Midway.* New York: Penguin, 1982. John Prados *Combined Fleet Decoded: The Secret History of American Intelligence and the Japanese Navy in World War II.* Annapolis, MD: Naval Institute Press, 1995. Katherine L. Herbig, "American Strategic Deception in the Pacific: 1942-44," in Michael I. Handel (ed.), *Strategic and Operational Deception in the Second World War.* London: Frank Cass, 1987. Ronald Lewin, *The American MAGIC: Codes, ciphers and the defeat of Japan.* New York: Farrar Straus Giroux, 1982. Edwin P. Hoyt, *The Last Kamikaze - The Story of Admiral Matome Ugaki.* New York: Westport Praeger, 1993. Dallas Woodbury Isom, "The Battle of Midway: Why the Japanese Lost," *Naval War College Review*, Summer 2000. http://www.nwc.navy.mil/press/Review/2000/summer/art3-Su0.htm. Jonathan B. Parshall, David D. Dickson, and Anthony P. Tully, "Doctrine Matters: Why The Japanese Lost At Midway," *Naval War College Review*, Summer 2001. Mark E. Miller, *The Integration of Operations and Intelligence: Getting Information to the Warfighter* Maxwell AFB, AL. Air Command and Staff College, March 1997. Paul J. Jaeger, *Operational Intelligence at the Battle of Midway.* Newport, RI: Naval War College, Joint Military Operations Department, May 1998. Valerie A. Moule, *A Comparison of Operational Leadership in the Battle of Midway.* Newport, RI: Naval War College, Department of

Events, Intelligence, And Evidence Obtained by JN Before the Battle of Midway	
Date	*Events and evidence*
Operations, November 1995. Douglas Porch and James J. Wirtz, *Strategic Insight: The Battle of Midway*. Naval Postgraduate School, Monterey, CA. Center for Contemporary Conflict, National Security Affairs Department, June 4, 2002. http://www.ccc.nps.navy.mil/nsa/index.asp. Patrick D. Weadon, "Battle of Midway: How Cryptology enabled the United States to turn the tide in the Pacific War," National Security Agency, http://www.nsa.gov/docs/history/AFWater.html.	

Appendix 2

Evaluating JN Hypotheses supported by Evidence (likelihood of hypothesis given evidence): $p(H_i\|E_i)$			
	Hypotheses		
Evidence	*H1:* U.S. will respond to JN invasion of Midway	*H2*: U.S. will *not* respond to JN invasion of Midway	*H3:* U.S. will be waiting near Midway
U.S. carrier raids: Indicates ineffectiveness of JN ISR.	N	Y	Y
U.S. carriers surprise Landing Forces: Indicates effectiveness of U.S. ISR.	N	N	Y
Kido Butai Surprised in Indian Ocean: Indicates ineffectiveness of JN ISR.	N	Y	Y
JN traffic analysis correctly indicates Doolittle Raid.	Y	Y	N
U.S. units occupying French Frigate Shoals: Operation K forestalled	N	?	Y
JN SIGINT: detected U.S. carrier force in Coral Sea	Y	N	N
JN Naval Staff assumes U.S. has two remaining carriers	Y	Y	N
JN air reconnaissance: two U.S. carriers in Solomons Islands.	Y	?	N
JN COMINT: two U.S. carriers in Solomons Islands.	Y	?	N
JN COMINT: Midway short on water, Hawaii will re-supply.	Y	N	?
All Japanese aerial reconnaissance to Midway destroyed.	N	?	Y
JN Combined Fleet Estimate: "two enemy carriers—either in Australia or Hawaii."	Y	Y	N
JN intelligence on Aleutians out-of-date & inaccurate	Y	Y	Y
JN indications of U.S. readiness and preparedness for Operation MI.	N	N	Y
JN Naval Staff estimates: Americans had discovered Midway operation, might ambush *Kido Butai.*	N	N	Y
Kido Butai estimate: no enemy carriers in vicinity.	Y	Y	N
U.S. Spot JN Invasion Force where predicted	N	?	Y
U.S. carriers within 150 miles of *Kido Butai.*	N	N	Y
Totals	Y 9 N 9 ? 0	Y 7 N 6 ? 5	Y 10 N 7 ? 1

Appendix 3

Evaluating JN Evidence and Hypotheses (likelihood of evidence given hypothesis-True and hypothesis-False): $p(E_i \mid H_j)$ & $p(E_i \mid \sim H_j)$			
	Hypotheses		
Evidence	*H1:* U.S. will respond to JN invasion of Midway	*H2*: U.S. will *not* respond to JN invasion of Midway	*H3:* U.S. will be waiting near Midway
U.S. carrier raids: Indicates ineffectiveness of JN ISR.	N	N	Y
U.S. carriers surprise Landing Forces: Indicates effectiveness of U.S. ISR.	N	N	Y
Kido Butai Surprised in Indian Ocean: Indicates ineffectiveness of JN ISR.	N	N	Y
JN traffic analysis correctly indicate Doolittle Raid.	Y	Y	N
U.S. units occupying French Frigate Shoals: Operation K forestalled	N	Y	Y
JN SIGINT: detected U.S. carrier force in Coral Sea	Y	Y	N
JN Naval Staff assumes U.S. has two remaining carriers	Y	Y	N
JN air reconnaissance: two U.S. carriers in Solomons Islands.	Y	Y	N
JN COMINT: two U.S. carriers in Solomons Islands.	Y	Y	N
JN COMINT: Midway short on water, Hawaii will re-supply.	Y	Y	?
All Japanese aerial reconnaissance to Midway destroyed.	N	N	Y
JN Combined Fleet Estimate: "two enemy carriers—either in Australia or Hawaii."	Y	Y	N
JN intelligence on Aleutians out-of-date & inaccurate	?	?	?
JN indications of U.S. readiness and preparedness for Operation MI.	N	N	Y
JN Naval Staff estimates: Americans had discovered Midway operation, might ambush *Kido Butai.*	N	N	Y
Kido Butai estimate: no enemy carriers in vicinity.	Y	Y	N
U.S. Spot JN Invasion Force where predicted	N	N	Y
U.S. carriers within 150 miles of *Kido Butai.*	N	N	Y
Totals	Y 8 N 9 ? 1	Y 9 N 8 ? 1	Y 9 N 7 ? 2

ENDNOTES

[i] The idea that Krypton release might be used for such a nuclear bluff has been suggested by, among others, Carnegie Endowment for International Peace analyst James Wolfsthal; c.f., Merrill Goozner, "Nuclear Blackmail: The growing North Korean threat -- and why containment may still be our best means of staving it off." *The American Prospect*, August 8, 2003. http://www.prospect.org/print-friendly/webfeatures/2003/08/goozner-m-08-08.html On Krypton-85 as a nuclear enrichment indicator, see Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction.* OTA-BP-ISC-115, December 1993; David E. Sanger and Thom Shanker, "North Korea Hides New Nuclear Site, Evidence Suggests," *New York Times*, July 20, 2003; George Wehrfritz and Richard Wolffe, "How North Korea Got The Bomb," *Newsweek* (International Edition), October 27, 2003; and interview with David Albright, president of the Institute for Science and International Security, Washington, DC. CNN Aired May 11, 2003 - 17:00 ET http://cnnstudentnews.cnn.com/TRANSCRIPTS/0305/11/nac.00.html

[ii] The Bayesian ACH BBN is more conservative in other directions as well. That is, if the facts are that there is *no* nuclear enrichment, and there *is* pipeline testing, the observation of Krypton is less likely to suggest deception to Bayesian reasoners. In the non-Bayesian ACH BBN, no nuclear program *and* pipeline testing yields 7:3 odds in favor of the deception hypothesis; while the Bayesian ACH BBN reflects the more conservative 5:5 odds for deception; that is, the Bayesian conclusion is that Krypton could be due to deception *and* the testing, or to just the testing alone. Similarly, when pipeline testing can be ruled out, the non-Bayesian ACH BBN yields 7:3 odds in favor of enrichment and 4 to 1 odds against deception; while Bayesian ACH BBN conservatively considers the same evidence as reflecting 6:4 odds for enrichment and 4:6 odds for deception.